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A New Approach to the Financial Management of a Radiological Department

by
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Academic dissertation

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ABSTRACT

Radiology is a very rapidly developing specialty. During the last two decades new modalities, such as US, CT and MRI, have been introduced and are developing rapidly. The newest revolution is in the digital department with PACS, where the entire radiological diagnostic work-up is filmless and managed on an electronic basis. This will change the whole hospital workflow. To accomplish this, however, we need high capital investments.

In western countries the population is ageing and the need for health-care investments is increasing, but the money spent here is tending to decrease. With these conflicting requirements there is a pressing demand for methods to manage the resources available. These methods have to cover effectiveness and cost studies, cost analysis of radiological diagnosis and treatment, and also departmental management and leadership.

An ABC (activity based costing) method has been developed for radiology and found to be significantly more accurate than the conventional methods. It gives detailed information on cost data for the different departmental activities.

In the following paper, the cost and cost structure of a partially digitized radiological department and conventional radiology has been analysed using plain film as an example. The costs were calculated by ABC costing. The costs of a partially digitized department are higher than those of conventional radiology.

The cost-effectiveness of the developing radiological technology was studied, using meningioma as an example. The costs of diagnosing a meningioma have decreased dramatically from the time before CT to the time of CT and further to the time of MRI. Simultaneously the investigations have become more accurate and also more convenient for the patients.

The cost-effectiveness of radiological procedures was analysed in an observational study, using the treatment of chronic critical ischaemia of the legs as an example. PTA was found to be more cost-effective than vascular surgery.

Furthermore, management methods were analysed. In resource management (RM) the basic elements are to generate commitment of all the important groups of persons and at the same time, to give and share information that is important for staff education. The continuous quality improvement (CQI) method is a new one, based on measured data and commitment of all the working groups involved. The method was found to be more effective than the conventional one. Activity-based management could be used the in the same manner, having measurements made according to activity costs.

The overall conclusion to be drawn from these individual studies is that the new management methods are applicable in health care provide useful tools for managing a radiological department.

ABBREVIATIONS

ABC	Activity-based costing
ABI	Ankle brachial index
ABM	Activity based management
CQI	Continuous quality improvement
CR	Computed radiography
CT	Computed tomography
DRG	Diagnosis related group
EBM	Evidence based medicine
EEG	Electroencephalography
EPR	Electronic patient record
EU	European Union
EUR	Euro
FIM	Finnish mark
HIS	Hospital information system
HUCH	Helsinki University Central Hospital
MRI	Magnetic resonance imaging
OUH	Oulu University Hospital
PACS	Picture archiving and communication system
PEG	Pneumoencephalography
Pareto	Rank order histogram
PDCA	Quality improvement method, with the following steps; plan, do, check, act.
PTA	Percutaneous transluminal angioplasty
RIS	Radiology information system
RM	Resource management

RCT	Randomised controlled trial
SPC	Statistical process control
TQM	Total quality management
US	Ultrasonography
USA	United States of America
USD	United States dollar

LIST OF ORIGINAL PAPERS

This thesis is based on the following publications:

1. Laurila J, Suramo I, Brommels M, Tolppanen EM, Koivukangas P, Lanning P, Standertskjold-Nordenstam G, Activity-Based costing in Radiology: Application in a paediatric radiological unit. Acta Radiol. 2000 41(2): 189-95.
2. Alanen J, Keski-Nisula L, Laurila J, Suramo I, Standertskjold-Nordenstam CG, Brommels M. Costs of Plain-Film Radiography in a Partially Digitised Radiology Department: An activity-based cost analysis. Acta Radiol. 1998 39 (2): 200-7.
3. Laurila J, Suramo I, Brommels M, Servo A, Kotikangas J, Standertskjöld-Nordenstam C. -G. Diagnosis of Meningioma**:** A comparison of costs before CT, during CT and after introduction of MRI, Acta Radiol 2000 41 (6): 539-543.
4. Laurila J, Brommels M, Standertskjöld-Nordenstam CG, Leinonen S, Lepäntalo M, Edgren J, Suramo I. Cost-effectiveness of percutaneous transluminal angioplasty (PTA) versus vascular surgery in limb-threatening ischaemia. International Journal of Angiology 2000 9 (4): 214-219.
5. Laurila J, Standertskjöld-Nordenstam C. -G., Suramo I, Tolppanen E-M, Tervonen O, Korhola O, Brommels M. The efficacy of a continuous quality improvement (CQI) method in a radiological department: comparison with non-CQI control material. Acta Radiol. 2001 42 (1): 96-100.

1. INTRODUCTION

Radiology is developing rapidly; new modalities from the recent decades are US, CT and MRI. The latest revolutionary technology is the digital department with its picture archiving and communication system (PACS); the entire radiological diagnostic work-up is filmless and managed on an electronic basis. This process has changed workflow of the whole hospital.

Radiology has assumed a steadily increasing role in health care. One can say that every patient in a hospital visits the radiological department at least once. Often the radiological diagnosis is conclusive in planning the patient's treatment. The efficiency of a modern hospital is directly influenced by the quality and efficiency of its radiological services. (66)

The need for health-care investments is increasing, as the populations of Western countries are ageing, yet the money spent is tending to decrease. This conflict needs to be settled, which explains the great demand for new methods for managing the resources available. Such methods should cover both quality and economic issues, i.e. the cost and the effectiveness of the processes of patient care, as well as departmental management and leadership.

Recent years have seen the introduction of new management methods, such as resource management, quality management and activity management. In all these methods the same basic principles are relevant. All the personnel groups involved in the area managed should participate in its management, in order to ensure commitment for managerial actions and for collecting the data needed. In managing the whole procedure should be thought of as a process that has to be analysed from

start to finish; it should reach across the borders of the individual departments. This process has been described as workflow, a decision tree, a diagnostic or treatment process or a critical pathway. Methods are needed to measure the quality and costs of the process. When managerial changes are implemented, there should be control measurements for evaluating the effect of the management procedure. A cycle for continuous improvement, initially introduced in quality management, is now an important part of other managing methods as well.

Only a few articles have been written on management in radiology, although some are to be found in the literature on cost accounting, effectiveness and efficacy, as well as economy. There are several articles on quality management, but only one editorial, without any mention of study material, on resource management and activity-based management. (1, 86) Thus scientific studies of management in radiology are needed.

2. REVIEW OF THE LITERATURE

2.1 Management of Health Care

The organisational system forms an important basic economic ground of the measurement of system. Since it is not possible for central managers to have all the relevant information and time to determine the detailed plans for all the organization, some degree of decentralization is essential. The basic units are usually called as responsibility centres.

There are four basic types of responsibility centres: (35)

1. In **cost or expense centres** managers are normally accountable for only those costs that are under their control. In the standard cost centres the output can be measured and the input required to produce each unit can be specified. Discretionary expense centres are those centres where output cannot be measured in financial terms and there are no clearly observable relationships between the inputs (the resource consumed) and the outputs (the results achieved)

2. **Revenue centres** are responsibility centres where managers are accountable only for financial outputs in the form of generating sales revenues. In the Finnish health care system there are hardly any centres of this type.

3. Both cost and revenue centre managers have limited decision-making authority. A significant increase in managerial autonomy occurs when unit managers are given responsibility for both production and sales. They are called **profit centre**.

4. **Investment centres** are responsibility centres whose managers are responsible for both sales revenues and costs and, in addition, have responsibility and authority to make working capital and capital investment decisions. Investment centres represent the highest level of managerial autonomy.

In the functional organizational structure all activities of similar type within a company are placed under control of the appropriate department head. The organization as a whole is an investment centre and below this level a functional structure applies throughout.

In divisionalized organizational structure the organization is split up into divisions in accordance with the products produced. The organization is divided into separate investment or profit centres and a functional structure applies below this level. For successful divisionalization it is important that the activities of a division be as independent as possible of other activities and relations between divisions should be regulated so that no one division, by seeking its own profit, can reduce that of the company as a whole. (35)

In Finland, hospitals are mostly managed by a board of directors consisting of politicians, with health care professionals as expert members. Hospital management has, generally speaking, three lines, but nowadays there are some variations. There is a hospital director, who is responsible for general administration, financing and utilization of resources. The chief physician is responsible for the care of patients and for medical matters. The head nurse is usually responsible for professional standards in nursing as well as for recruitment of nurses. (18)

In the past decade, Finnish public hospitals developed from centralized directly managed institutions to decentralized structures turning departments into profit centres. The terminology used is not precise as the public administration framework was preserved and department heads have limited authority, although usually the head can make decision on the costs and minor investment, but not really on the sales or pricing. A profit centre can be a single specialty or a group of specialties.

In the past decade, product line management has been introduced in the health service in Finland and elsewhere in the industrialised world. (20) The services products provided by hospitals are expressed as diagnosis related groups (DRG) (92). Pure product line management in a hospital would be based on departments, providing direct patient care, whereas medical services departments like radiology would be defined as support units. It is more useful to view the entire organization as a matrix, containing both the product lines, according to DRG, and service units, such as radiology. (19, 38)

The basic focuses for management are usually personnel, economy and quality. When we are dealing with health care, the basis of economic efficiency is the efficacy and effectiveness of patient care interventions. There is now a demand for so-called evidence-based medicine, EBM. In radiology, investments are larger than in the health care sector in general, which explains why management in radiology is focused chiefly on investment. Another important aspect is the process of diagnosis and treatment of services. Actually, the patients go through the process in different departments of the hospital and pass from primary to secondary care and then return to primary care. (69, 92, 101, 103)

In hospital settings it has been found that both physicians and nurses should participate actively in the management of departments and the hospital as a whole. (37, 59, 86) There, the physicians have been "the patients´ advocates" and cost-consciousness has not been their major concern creating certain ambivalence in their attitude in managing. Politicians and administrators have been responsible for the cost-savings and cost-control. In Finland, until the late 80´s, physicians were not interested in becoming involved in hospital management, but in the late 90´s Enckell observed great changes in this respect not only among physicians, but also nurses. (37)

In America it is said that medical staff in hospitals spend an extraordinary amount of their formal and informal time criticising, doubting, and questioning the motives of the lay administration. Administrators, in turn, fret about the clinicians, who do not seem to be "controllable" or willing to behave realistically about inevitable organisational constraints. Little energy is left for collaborative improvement. (13)

The greatest difference between systems in the Nordic countries and in the USA is that in the USA setting the majority of the physicians and surgeons are private contractors working on their own, and only loosely attached to the hospital. In the Nordic system the clinicians are all employees of the hospital. Consequently it is easier to introduce new management methods successfully in the Nordic countries because the medical staff is more committed to the hospital. (18).

2.1.1Resource management (RM)

The key issues in resource management are said to be shared understanding and agreement by all participants, including clinicians, nurses and managers. To achieve ownership, they have to participate in the design of the system. They must have information showing how the resources are being used. (59, 86)

In the UK, resource management was a government initiative aimed at involving clinicians in managerial duties. It was characterized by introducing a (specialty-based) departmental structure, one of the independent consultants (specialists) being named as responsible for clinical activities. Previously, each consultant was accountable only professionally and for his own activities. The new “lead physicians” are responsible both for patient care and for dealing with the resources (human, physical and financial) of a department. A second important feature of the resource management initiative was the commitment to provide information - covering patients as well as cost data - to the lead clinicians. The basic conceptual model resembles that of product-line management - linking responsibility for the quality of the final product and of the use of resources to one person, regardless of the organizational units participating in the process. (86)

In the USA settings, clinical studies have suggested that the average 350-bed hospital can reduce overall costs of patient care by 10-20 percent through effective utilization and control of resources. (79, 81) It has been stated that, in the hospital setting, resource management can be used in many different areas: clinical management, materials and supplies, labour and operations. Defined (ten) tools have been introduced for resource management. (81)

2.1.2 Total quality management (TQM)

In health care, methods already exist for managing quality. Inside the profession or interprofessionally auditing has been done. These take place typically at morning meetings in the radiological department, case presentations, postgraduate lectures, and morbidity and mortality meetings. Usually these activities concentrate on individual cases. They do not use systematic techniques to ensure that improvements in the service are made or evaluated. (13, 70)

In radiation protection, quality assurance is well known. The quality of equipment, film developing, films and light boxes is measured. In addition the scientific studies that are done in medicine are methods for evaluating the quality of the diagnostic or treatment methods. (69) The modern quality assurance method is clinical auditing, which just now beginning in Finland, because of the new legislation of radiation protection in EU.

Accreditation is used primarily for the professional profile. In order to become a qualified radiologist or technician, a person must work for a certain agreed time in different areas of health care and, in addition, must pass several tests during the study period. The same kind of accreditation methodology is nowadays also used for service quality, but it is then voluntary. (70)

Management quality is about designing the simplest and most efficient flow of work. It is a question of identifying and avoiding the problems that cause delays, mistakes and waste. Improving management quality increases productivity and, at the same time, cuts costs. (70)

A CQI (continuous quality improvement) process is a method for resolving managerial problems in work processes by analysis. The improvement phase of CQI, utilizes the PDCA (Plan-Do-Check-Act) cycle. The first step is planning, i.e. determining goals and defining methods to reach those goals. The second step is doing, educating employees and so implementing the change. The third step is checking, monitoring the effects of the changes; have the goals been achieved? If not, return to the planning stage. The fourth step is acting: taking appropriate action to institutionalise the change (94). A CQI process is usually described to consists seven steps: 1. identifying which process to improve, 2. establishing an expert team that knows the process, 3. clarifying current knowledge of the process, 4. understanding the causes of variation in the process, 5. selecting methods of improvement, 6. designing specifications, and 7. monitoring the specifications (78).

A flow chart is used in describing the process. Pareto analysis (a rank order histogram) is used for defining the importance of the potential reasons for the problems analysed. (13) It simplifies the complexity by making a visual representation of the relative importance of the potential reasons for the problems. They are analysed by cause and effect diagrams. An intervention is then performed on the basis of these data.

Initially developed and implemented in industrial settings, CQI has recently been used with success in health care institutions as well as in radiological departments. (1, 14, 15, 22, 23, 29, 45, 65,70, 85, 88, 89, 90) However the CQI process has been criticised because it is cumbersome and lengthy (45, 90).

2.1.3 Activity management (AM)

By providing improved information for strategic planning purposes, activity-based management (ABM) systems are said to help hospitals and other health care providers to improve the quality and efficiency of the care they provide and to reduce costs and manage their resources better. (1)

Activity-based management (ABM) aims at reducing costs and improving outcomes by streamlining the work process, seen as a flow of activities. It is said to derive useful information from the way people think (their activities) rather than from traditional expense categories. ABM is said to support outcomes, quality, teams, re-engineering, empowerment, and continuous improvement. (3)

Activity accounting is stated to provide information that is crucial for continuous improvement. Managers can use this information to eliminate “waste” in the workflow processes. Activity accounting is said to support continuous improvement. The traditional product cost model - which separately collects cost of labour, material, and the cost of the product rather than process - is not compatible with CQI and TQM philosophy; the effect of the change in a process on the cost of a product cannot easily be determined. (17)

Activity investment management is said to be used by the activity management approach. This evaluates the impact of changing an activity process, such as introducing new technology, on the cost, performance and interdependencies of activities. It decreases the probability of selecting and implementing an inappropriate investment by evaluating capital investments in relation to work procedures rather than to existing cost structures. It links investment opportunities to strategic

objectives and couples the accounting system with the investment analysis to facilitate corrective action. (17)

The strategic analysis of activities is said to be suitable for strategic analysis with an activity based management approach. It uses cost and performance data to develop enterprise strategies. Information obtained from traditional cost accounting systems is usually inadequate for strategic cost analysis, because it does not help the department to understand the behaviour or the costs from a strategic perspective. It follows that a company's accounting systems must be designed to facilitate strategic cost analysis - a function radically different from traditional record keeping. (17,35)

2.2 Management of Radiology

In Finland the radiological department is divided into medical and radiographic sections. The chief physician, who is a radiologist, is responsible for patient care and medical matters as well as recruitment of radiologists. The chief radiographer is usually responsible for professional standards in nursing as well as for recruitment of radiographers. During the past decade profit centres have been created in which the chief physician is also responsible for economic matters. In many instances there may be several specialties in the profit centre, often a laboratory and pathology department, and the chief physician also has responsibility for the economics of these other specialties. In Helsinki and Oulu, the Departments of Radiology were very similar. They constituted their own profit centre during the study period. (18, 69)

Typically, the hospital sells its services almost solely by hospital days or by a modification of the DRG. These services are not direct products of the radiological department. This can raise problems when the hospital is allocating its economic resources. Radiology is not always the first in line. Therefore it is crucial that the methods used should show the importance and usefulness of radiological services. This should also be shown in terms of quality, added value and cost savings and, whenever needed should be compared with other methods of diagnosis and treatment. (44, 69, 92, 101)

The added value is better estimated in interventional radiology, when comparing with other alternatives, such as surgical operations. In diagnostic methods it should be more focused on the influence of the examination on subsequent decisions about clinical management.

Radiology differs from other specialities in the rapid development of its technology and the high cost of its equipment. It is important to run the department effectively despite the rapid changes and bearing in mind the effective use of the equipment. (68, 69, 92, 101)

2.2.1 Cost and effectiveness of radiological procedures

During the last 30 years radiology has seen major advances, i.e. computed tomography (CT) and magnetic resonance imaging (MRI). As the equipment for these two processes is expensive, radiology has raised a number of cost considerations. Consequently many authors call for an evaluation of these imaging methods in terms of their efficacy, efficiency, effectiveness and costs. However there have been only a few studies on costs and efficacy, and these have mainly concentrated on CT. (44, 63, 74, 77, 92, 98, 101, 102, 105)

Computed tomography (CT) and magnetic resonance imaging (MRI) were introduced with a time interval of approximately 15 years. Before, between and after these landmarks, neuroradiological diagnostic procedures stabilised in eras of relatively standard practice. In many neurological disorders, other diagnostic methods were of limited significance, and any observed changes in diagnostic practices can, therefore, be attributed to largely these changes in radiological technology.

2.2.2 The picture archiving and communication system (PACS)

In the past decade there has been a rapid increase in the use of the digital radiographic technique. Many radiological departments have installed a picture

archiving and communication system (PACS). PACS systems vary from large, hospital-wide installations aimed at the filmless hospital to mini-PACS that link a few workstations to CT, MR, and a local digital image archive. Parallel with this development, it has also become common place to use computed radiography (CR) without PACS in skeletal and chest radiography. Owing to economic restrictions on health care in Europe, the transition from a conventional film-based system to a digital filmless hospital in one step is usually impossible, and the change has to be performed step by step. The proportion of digital modalities has gradually increased over the years and seems still to be increasing, despite the higher initial investment as compared with conventional equipment. Arguments used in favour of acquiring digital equipment point to such benefits as lower costs, rationalisation of technical operations, and the higher quality of the images produced (5, 27, 96).

The effect of digital plain-film radiography on the operating costs of a radiology department has been examined mainly in hospitals where radiological imaging is almost totally digitized. (4, 11, 26, 34, 68, 75) Cost analyses have also been published on the use of CR for patients in intensive care units with reduction of the costs of examinations. (33, 72,103) However, reports on the costs, of using CR in skeletal and chest radiography are few and their results are contradictory. (4, 11, 26, 27, 33, 34, 68, 72, 75,103) As a rule, these analyses have been based on traditional cost accounting.

On the whole, the benefits in terms of costs are becoming more evident. This is certainly because of the development of the technology and of the ways of implementing it. The way the work is done using the PACS is seen to be increasingly important. The PACS should make working both in and outside the radiological department as easy and as rapid as possible. This lowers the costs. The basis is to

have the RIS (RIS can be seen a part of HIS), the brain of PACS, driving the archive. Folder management and workflow management are the newest important components of the PACS. They make the work faster and easier, at the same time decreasing the time spent on individual examinations. From a clinical point of view the PACS should be an elementary part of EPR (electronic patient record). There should be a possibility to view electronically radiological data simultaneously with the whole patient clinical history. This makes the work more effective. There are not yet many functional installations of EPR, but the development is intensive.

Resources are known to be limited, but at the same time the population is growing older and as medical technology develops, it often needs large and continuous investments. Older people use more health care resources than younger ones. This emphasises the question of how to make the most effective use of the resources that are available for health care.

This is of special concern in radiology, which needs big investments in technology and information technology alike. The price of a unit of equipment is often more than 1 million euros. This has led to concern that the new technology only increases the costs, but gives meagre returns in terms of more cost-effective diagnostic and therapeutic services. Consequently, many authors call for the evaluation of imaging methods in terms of their efficacy, efficiency, effectiveness and costs. (30, 44, 63, 74, 77, 92, 98, 104, 105)

At present radiology is undergoing a period of costly development, with implementation of digital modalities, PACS, teleradiology and other communication and information systems. (68) All this increases the importance of effective management of investments, as compared with other health care sectors. Another

important issue compared with other sectors of health care is the rapid development of radiological equipment and technology along with the general development of information technology.

2.3 Managing Resources in Radiology

In health care and in management it is important to know what is measured. Especially in management, it is also important to know the consequences of measurement. Therefore, what is important should already be decided at the start, followed by specifications, and then choose the methods to be used for measuring performance. Inadequate measuring can be very costly as well as misleading. (71)

From managerial aspect it is important that the target individuals know what the aim of the project is. Various research studies suggest that the existing of a clearly defined quantitative target is likely to motivate higher performance rather than vague statements such as “do your best”. It is also difficult for employees or their superiors to interpret performance unless actual performance can be compared against predetermined standards. (35)

Result controls involve the following stages: (35)

1. Establishing results (i.e. performance) measures that minimize undesirable behaviours
2. Establish performance targets
3. Measuring performance
4. Providing rewards and punishment

In health care it is important to measure both the process and the outcome. (71) In radiology the evaluation of imaging tests and treatments of patients, in terms of their efficacy, efficiency, effectiveness, outcomes and costs, is becoming increasingly important. (30, 44, 92, 101)

2.3.1 Cost-effectiveness

Efficacy describes the technical relationship between the technology and its effects. Effectiveness concerns the extent to which applications of an efficacious technology brings about desired effects. Efficiency is an economic concept, which relates efficacy and effectiveness to resource use. Cost-effectiveness analysis is a method where the costs of a health technology are compared to its effects. (63, 102) Analysis of cost-effectiveness is both a paradigm for understanding a decision and a methodology for optimising decision-making. (39, 43) The methodology cannot be adopted directly from other areas of health care. Variables should more often be selected to define value in terms of the influence of the examination on subsequent decisions about clinical management. (43)

The diagnosis of meningioma has been based on radiological methods during all three eras of technological development (31, 42, 67, 87, 95). However there have been only a few studies on costs and efficacy, and these have mainly concentrated on CT. (44, 63, 74, 77, 92, 98, 102, 105) The improvements in diagnostic accuracy have been described in several articles. CT reduces the need for invasive examinations. (67,105) Shortening of hospital stays has also been reported. The same effects have been found when using MRI: diagnostic work-up and management plans are affected favourably. (30)

Vascular reconstruction is the accepted treatment of choice in leg-threatening chronic ischaemia caused by advanced occlusive arterial disease. Revascularisation procedures are justified because of the better mobility and quality of life, as well as lower long-term costs, as compared with the other option, amputation. (21, 28, 61) There are reports advocating the use of endovascular techniques even in patients in whom amputation was previously seen as the only possibility (21, 32, 51).

Percutaneous transluminal angioplasty (PTA) is an increasingly important mode of treatment of patients with ischaemia of the lower limb (64, 32,50,53). This method has been reported to have a slightly lower patency rate than vascular surgery. (16, 21, 28, 32, 49, 54, 76, 100,104) However, in selected groups with intermittent claudication, the only two prospective randomised studies comparing PTA with bypass surgery showed no significant difference in patency rates between transluminal angioplasty and vascular surgery. (46) PTA has a lower mortality rate (28) and, according to data collected from separate studies on PTA and surgery, is a less expensive alternative than surgery in terms of the actual procedural costs and the costs of hospital stay. (28, 32, 58, 99) Earlier comparative cost studies show that primary hospital costs for PTA are 19 to 53% of that for bypass surgery (21, 32, 60).

2.3.2 Cost accounting in radiology

A cost and management accounting system should generate information to meet the following requirements: (35)

1. Allocate costs between costs of goods sold and inventories for internal and external profit reporting.

2. Provide relevant information to help managers make better decisions. Provide information for planning, control and performance measurement.

Typically cost systems are classified as follows: (35)

1. Direct costing system is appropriate for decision-making where the cost of those joint resources that fluctuate according to demand are insignificant. Negative or low contribution items should then be highlighted for special studies. The disadvantage of direct costing system is that systems are not in place in order to measure and assign indirect costs to cost objects.
2. Traditional absorption costing systems
3. Activity-based costing system

Both traditional and activity-based costing systems (ABC) assign indirect costs to cost objectives. The ABC system allocates overheads on a cause-and-effect basis and more accurately measures the relatively high level of overhead resources consumed by product.

Conventional cost accounting has failed to keep pace with the evolution of product and process technologies in radiology. The result is distortion of product costs and aggregate cost information. Measures of performance tend to be short-term and do not adequately reflect the fluctuation in the organisation’s economic position. (25, 40, 55) As a result of technological changes the proportion of costs directly attributable to procedures tends gradually to decrease, thus increasing the importance of correct handling of the overhead costs. Conventional costing overcosts high-volume products and undercosts low-volume products, thus giving a false picture of the relation between production and costs (2, 35).

Activity based costing (ABC) is a way of gaining insight into the true costs and of solving problems of the accounting. ABC has been used successfully in various manufacturing and servicing organisations. Interest in implementing the method in health care is increasing. (9, 10, 21, 36, 41, 47, 52, 57) ABC provides more precise product cost information than a conventional costing system. (21) The accuracy of budgets can be increased. The method helps to trace activities that do not add value to the procedure. Eliminating those can optimise processes. Product costing is more detailed, which makes evaluation of the effectiveness of the examinations and treatments more precise. (57)

Radiological procedures are service products with a large number of indirect costs. It is difficult for hospital administrators and radiologists to meet the challenge of cost containment adequately without knowing the individual components of procedural costs. The time required to perform procedures varies widely, depending on the patient's condition and the staff and equipment used (6,7). Radiological procedures require many activities in addition to the actual imaging. Important determinants of the final product and its quality are time scheduling, registration of patients at the registration desk, analysis of examinations and conferences. Product development and quality assurance are also needed and, in a university hospital, teaching and research imply important indirect costs. For efficient management of the radiology department, information on the resource utilisation of all these activities is essential.

2.3.3 Statistical methods to support the quality improvement

The earlier mentioned efficacy, efficiency, effectiveness and outcomes are methods for measuring clinical quality. Statistical process control (SPC) is a method specially designed to assess quality indicators and their variation. All these methods were developed to implement a process of continual product improvement, while achieving

compliance with production standards and other requirements for promoting customer satisfaction. SPC involves the use of statistical tools, such as histograms and control charts, as well as problem-solving techniques, such as flow-charts, cause-and-effect diagrams, and Pareto charts. (73)

A flow-chart can be described as a process chart, including all the important steps in the diagnosis or treatment of a patient or workflow. All the possible causes of a consequence are illustrated by a cause-and effect diagram, often called a fishbone. All the causes are illustrated on the left side and the consequences are illustrated on the right side. (60)

A graph is a pictorial way of summarising data. Common types of graph include line charts, pie charts, bar charts, scatter charts and histograms. In a line chart the values are united with a line, clearly illustrating the changes of one value with the changes in another. In a pie chart the values are presented as a “pie” composed of sectors, the width of the sectors illustrating the relative significance of the values. In a bar chart the values are represented by the lengths of the different bars in the diagram. A scatter diagram is a special type of graph, which shows the relationship between two variables. A histogram is used to summarise the frequency of occurrence of something, in the sample data. (94)

Pareto (rank order histogram) and control charts are tools used to analyse and improve the quality of an on-going process. Pareto charts focus attention on the most important category among a wide variety of possibilities. They simplify the complexity by making visual representations of the relative importance of the potential causes of problems.

Control charts help to differentiate between random variations and variations that are meaningful in a process. (12, 60) There are several different kinds of control charts: (60)

1. An X-bar chart is a line fluctuating between bars, each point representing the mean of a measured value within a subgroup.
2. X-Bar and R-charts show the mean of a measured value within each subgroup of the chart and the range of values within each subgroup.
3. A P-chart shows the number of nonconforming units as a fraction of the total number of units in each subgroup. (Paper V, figures 2, 3)
4. An NP-chart shows the number of nonconforming units in each subgroup.
5. A U-chart shows the number of nonconformities as a fraction of the total number of units in each subgroup.
6. A C-chart shows the number of nonconformities in each subgroup.

3. PURPOSE OF THE STUDY

The purpose of this study was to analyse, understand and improve the cost management of the very rapidly developing and capital-intensive speciality of radiology, as follows:

1. Changes in management caused by evolving radiological methods in a historical perspective.
2. Possible benefits of calculating cost-effectiveness as compared with mere outcome measurements when evaluating radiological interventions.
3. The feasibility and usefulness of activity-based accounting as compared with conventional costing of radiological services.
4. The value of the instruments used in total quality management (TQM) for handling the process of producing radiological services.

4. MATERIALS AND METHODS

The material and methods will be described in detail as relevant to each paper.

4.1 Subjects (Papers I-V)

Paper I

Paper I is the first paper in the literature to study the way activity based costing should be done in radiological departments and to analyse the differences from conventional costing methods.

The study was made in the radiological department of Oulu University Hospital, consisting of four units. We made a comparative study of the paediatric unit. This is a distinct entity and the procedure mix consisted of basic radiological examinations. The material comprised of 7, 452 radiological examinations performed in the unit between 1 st January to 30 th June 1994. There were 5, 562 plain radiographs, 233 fluoroscopies and 1, 657 ultrasonography. A total of 260 examinations were performed in the wards or in the intensive care unit.

Paper II

Paper II is a study of the costs and cost structure of plain-film radiography in a partially digitized department using the earlier developed activity-based costing method for the radiological department.

The study material was gathered at the Central Hospital of Vaasa, a medium-sized general hospital with approximately 500 beds. In 1994, the radiology department performed about 46, 000 examinations (paper II, table 1); 34, 140 (75%) of them were skeletal and chest radiographs, of which approximately 3/4 were carried out with CR, and 1/4 with conventional film-screen radiography (paper II, table 2).

The material consisted of the plain film radiographic examinations (plain-film examinations) made in the radiology department during 1994. The examinations were divided into three groups: CR (other than chest CR examinations), chest CR examinations, and conventional plain-film radiography. The distribution of the examinations was equally divided between the groups of computed and conventional plain-film radiography.

Paper III

Paper III analyses the cost and effects of the developing methods of radiological diagnostics, with meningioma as an example, in the time periods before CT, during CT and after the introduction of MRI.

The study site was Helsinki University Central Hospital, with a local catchment area of 1.1 million and tertiary-care responsibility for an additional 0.3 million inhabitants. We chose the years 1976-7, 1984-5 and 1992, respectively, to represent the three typical eras of technology. We collected data on all patients with meningioma in the study periods. We found 20 such patients (13 females) in 1976-7, 22 (16 females) in 1984-5 and 16 (11 females) in 1992. The mean age of the patients was 45.8 years in 1976-7, 52.7 years in 1984-5 and 46.5 years in 1992.

Paper IV

Paper IV is a study of the differences in cost-effectiveness between the two methods of treating limb threatening vascular ischaemia PTA and vascular surgery.

In Finland, all cases of vascular surgery and PTA are reported to a national register known as Finnvasc (covering more than 4, 000 procedures annually). (56, 61, 84) Each hospital has a minivasc register, which supplies information to the national registry. Two of the three largest vascular centres in Finland, i.e. the university hospitals of Oulu and Helsinki, reported a total of 772 femoro-popliteal vascular reconstructions and PTAs carried out between 1 January 1991 and 31 December 1992. Data from a three-year-long follow-up were available for every patient.

Paper V

Paper V analysed the efficacy of CQI methods as compared with conventional management. The study material was from HUCH and from OUH at the same time, October 1993 - February 1994, with follow-up eight months after the intervention. The material was from the respective round-the-clock departments of radiology.

4.2. Methods

Paper I

The conventional costing system had been used since 1992. Items were grouped under five cost groups: payroll, equipment, materials and supporting services, facilities and overhead costs.

The costs were calculated in the same way in the two costing methods. Annual costs were calculated using a straight-line depreciation charge and including a 10 per cent opportunity cost in addition to the depreciation cost (107, 108). The administration costs of the radiological department were not included, because these could not be allocated to only one of its four units.

Planning of the ABC model was done by an expert group, including representatives from the main personnel categories, the senior radiologist, the head radiology technician and the assistant head radiology technician. Their first task was to identify all the activities required for carrying out the radiological procedures. Then all the resource types required for these activities were identified.

A radiological procedure could be described by listing the activities in a time sequence. Eight activities were identified: 1. Time scheduling and registration, 2. Direct procedure, 3. Subsidiary procedure, 4. Development of films, 5. Interpretation of procedure and typing, 6. Conferences of clinicians, 7. Quality assurance and product development and 8. Research and teaching. A basic process model was designed for each of the three different product lines of the unit: plain radiography, fluoroscopy and ultrasonography.

Since there are usually a great number of different resources, these were grouped into larger resource "pools", for easier handling. Resources were then allocated to activities and subsequently to specific radiological examinations. In the allocation, so-called cost drivers were used; these include any causal factor that influences resource utilisation, usually time, number or volume. In micturition cystography for instance, the time used for an examination is a cost driver for clinicians and radiology technicians and the number of procedures is a cost driver for equipment, materials, e.g. films (paper I table 3).

Resource pools and cost drivers were identified for each individual procedure. Resource pools were those explained in paper I, table 2. Rents, equipment, furniture and materials were allocated to the various rooms according to their use. The cost drivers were volume and time. An example is given in paper I, table 3.

Activities not covered by the RIS, such as product development, quality assurance activities, teaching and research work were calculated as an annual total and divided between procedures according to their volume (paper I table 4).

Paper II

In the second paper the amortisation period of all radiographic machines was taken as 15 years, except for the roentgen tubes, for which it was 3 years. Three cost comparisons were performed. In the baseline calculations, the amortisation period of the mini-PACS was set at 10 years and the interest rate for invested capital was defined as 0%. The method used was the activity-based costing method, as previously described.

Paper III

In paper III all the data on diagnostic examinations were presented as flow diagrams (decision trees, critical pathways) to illustrate the strategies used for examining each technological era.

In the third study, capital cost estimate was based on a capacity utilisation standard of 2, 000 hours per annum, found to be constant during the three periods. The annual capital cost was calculated as a straight-line depreciation charge and an opportunity cost (interest charge 8%). (18) The lifetime of the equipment was set at 10 years or, if longer, the actual operating time. For the MRI equipment in 1992, no calculation of depreciation was made, as the equipment was leased. The actual cost of the lease was set as the capital charge. The annual cost of maintenance was calculated from the actual cost data and expressed as a percentage of the purchase price. The percentage varied from 3.7% to 4.8%, depending on the piece of equipment

The final diagnosis of meningioma was used as an end point. Information on presenting symptoms, admission criteria and the diagnostic work-up were collected from the medical records. All data on diagnostic examinations were presented as flow diagrams to illustrate the strategies used in each technological era.

Paper IV

This paper describes the construction of a cost accounting model that was tested using data for interventional radiology and vascular surgery. Cost data were gathered until the end of the follow-up (1994). Hospital costs covering all the events from the time when the patient was referred for a vascular consultation to the three-year follow-up visit were collected from the hospital discharge data and the hospital

accounts. The data included hospital stay, stay in the intensive care unit, radiological examinations and operations. The unit costs of the procedures and the hospital stay are from the Helsinki cost-accounting system, which has detailed cost data of over 6, 000 procedures and activities.

The haemodynamic success of femoro-crural reconstruction was determined as an ABI increase of 0.10 or more. (82) In addition, leg outcome was assessed by the number of vascular reoperations and amputation-free years. Primary patency was indicated by an increase in ABI and its maintenance and no further intervention in the treated area. (82) Leg salvage was ended by a major amputation. Reoperations included any operation in the treated area - PTA, vascular surgery or major amputation. (82) Years of leg salvage refer to the number of years from the primary operation to the amputation. Reoperation-free years refer to the number of years until another operation was performed in the treated area.

Cumulative survival and patency were assessed using the life-table method. Cost-effectiveness ratios were calculated as costs per reoperation-free year and year of leg saved. They were calculated according to the formula CE=TC/LT/Y, where CE is the cost-effectiveness ratio at the end of the follow-up, TC is the total costs during the follow-up period, LT is the cumulative survival rate calculated by the life table method at the end of the follow-up, and Y is the number of years of follow-up. Cost-effectiveness was calculated after one, two and three years of follow-up. The SPSS statistical software (Copyright SPSS Inc.) was used in the statistical analysis. The statistical significance of any differences between the treatment groups was determined by means of the Wilcoxon-Gehan statistics of the life-table method, with the chi-square test or the t-test. The distribution of parameter values is illustrated by a boxplot indicating the median, upper and lower quadrants.

Paper V

A CQI program was implemented at HUCH in 1993. The program was supervised by a quality improvement team from the central administration. The team used outside consultants to teach the methodology to the staff. The teaching period was not included in the time of intervention, and responsibility for continuing CQI was then taken over by the departments involved.

A plain chest radiography examination was chosen as the measure of the function of the round-the-clock radiological departments. The highest acceptable time for the duration of a process was defined as two hours, with the agreement of the on-duty department clinicians. Any examinations lasting longer than two hours were considered not to conform to the experimental protocol (paper V, figures 2-3). The results were reported in one-hour batches as percentages of round-the-clock total chest radiography examinations.

At HUCH with the expert team, a flow chart was then drawn describing the process of an on-duty examination. For defining the importance of the reasons for any delay in the process, a Pareto analysis was used (12). At HUCH the problems and their remedies were discussed at the clinical meetings and in the CQI group. However, no continuous monitoring system was established.

At OUH there was no specific managerial project in progress, nor was there any support from the central administration. Only ordinary managerial methods were used. The problem was discussed at the clinical meetings and the remedy was designed on the basis of this discussion. The changes were also followed in the ordinary way. Discussion took place at the normal clinical meetings.

SPSS © statistical software was used for statistical analysis. The material for statistical analysis was collected at HUCH by a questionnaire and at OUH by X-RAY (i.e. by the local radiological information system). Control charts were used to compare process performance at different time periods.

5. RESULTS

5.1. Activity-based costing

In the radiological department, on switching from conventional costing to ABC, the overhead costs as a proportion of the total product costs dropped to one-fourth from the original USD 318 385 (57%) to USD 74 794 (16%) (paper I, figure 4).

In plain radiographic examinations the direct procedure costs accounted for only 30.8% of the total costs. The scheduling and registration costs (17.8%) amounted to more than half of the direct procedure costs (paper I, table 5).

5.2 Cost of digitalization of a radiological department

The baseline cost analysis (with the mini-PACS amortisation period defined as 10 years and the interest rate on invested capital as 0%) showed that the total costs of the CR examinations were 9% higher than those of conventional plain-film radiography (paper II, table 4). The costs of the chest CR unit were equal to the costs of conventional radiography. The capital costs of digital imaging were almost twice as high as the capital costs of conventional imaging. Personnel costs were lowest for chest CR imaging, but approximately the same in the other digital imaging modes as in conventional imaging. Film costs were the same in all groups, despite the higher price of the laser film used in digital imaging. Costs of premises, allocated hospital costs, and administrative costs were similar for digital and conventional imaging, although slightly lower for chest CR.

The higher cost of the digital investigations was due to the activity termed image processing, in which the phosphorus plates were loaded into the reader unit, processed on the workstation, and printed out on film by a laser printer (paper 2, figure 2, table 5). The cost of this activity was FIM 39 per examination (including FIM 18 in capital costs), i.e. 56% higher than the processing of a conventional radiograph, for which the cost was calculated at FIM 25 per examination (including FIM 3 in capital costs) (paper 2, table 6). The use of the workstation and the network as well as the archive amounted to about FIM 12 per examination. On average, 1.5 films per skeletal or chest examination could be saved by using the workstation to combine several images on one film sheet. Thus FIM 6 per examination could be saved by working with a workstation, compared to working without a workstation. This represents approximately 3-4% of the total cost of each examination

5.3 Cost-effectiveness of developing radiological diagnostic methods

For the diagnosis of meningioma in 1976-7, half the patients underwent electroencephalography (EEG) and plain skull radiography. The mean length of hospital stay for the diagnostic work-up phase was 11.5 days.

In 1984-5 all patients were examined with CT and angiography. The mean length of hospital stay was 5.0 days.

In 1992 almost all patients were examined with magnetic resonance imaging (MRI). The mean length of hospital stay was 2.7 days.

The total costs as well as the cost distribution changed considerably during the study period. The total cost of a patient's radiological examinations varied from EUR 293

in 1984-5 to EUR 235 in 1984-5 and to EUR 513 in 1992. The capital costs of radiological examinations more than tripled (paper 3, figure 2). The cost of materials also increased. Yet the payroll expense per patient decreased to one half, and the overall costs of the diagnostic work-up dropped to one third of the baseline (paper 3, figure 3). The biggest drop in expenditure was due to the reduction in the cost of hospital stay. The total costs of the diagnostic work-up decreased to one third of the original, i.e. from EUR 3 423 in 1976-7 to EUR 1 282 in 1992.

5.4 Cost-effectiveness of radiological treatments

PTA was less expensive, in terms of both treatment costs and total costs at follow-up. The average total cost of a PTA patient was USD 8 855. The total cost of a vascular surgery patient was USD 16 470. In both groups, the distribution of costs was skewed towards the lower end of the range. The cumulative costs over the follow-up period are presented as totals in paper 4, figure 4. The difference in cost is statistically significant ($p < 0.01$).

PTA had a better cost-effectiveness ratio than vascular surgery. On follow-up at three years the cost per reoperation-free year was USD 4 466 in the PTA group and USD 7 418 USD in the surgery group (paper 4, figure 5). The cost per year of leg saved was USD 3 877 with PTA and USD 6 055 with surgery (paper 4, figure 6).

5.5 Continuous quality improvement (CQI) method

As a result of the intervention, an added second radiologist in the evening, the percentage of examinations that took over 1 hour dropped from 34% to 16% (paper V, figure 2).

Regarding the long-term result, it was demonstrated that some of the gains has been lost by the time of the follow-up measurement (eight months after the intervention), but compared with the initial situation improvements were still observable (paper V, figure 2). In HUCH the radiologist was writing the report himself, but before the long-term measurement there was added a secretary for the evening.

After the reference measurement in the radiological department at OUH, the problem was solved by the traditional management approach without analysing the whole process: to call for the help of an extra off-duty radiologist when an excess of examinations accumulated. However, the percentage of processes lasting over 1 hour remained almost unchanged, and this was also the case at the follow-up measurement (paper V, figure 3).

6. DISCUSSION

6.1 Development of radiology

Radiology is a very rapidly developing speciality. During the last two decades new modalities, such as US, CT and MRI have been introduced. New methods have also been introduced in interventional radiology and they are still in process of rapid development. The newest introduction is the digital department with a PACS driven by HIS-RIS, where the entire radiological diagnostic work-up is filmless and managed on an electronic basis. This has changed the whole hospital, and specially radiology workflow. To accomplish this, however, high capital investments are needed.

The diagnostic work-up of meningioma during three eras of radiological technology shows that even high capital costs can be offset by reductions in expenditure on direct patient care (paper III). The introduction of CT and MRI changed the procedures dramatically and simplified the ways of reaching a diagnosis. The reduction in total costs was basically due to a radical shortening of the hospital stay for diagnostic examinations. In earlier studies, CT was shown to reduce the need for invasive examinations. (105) Shorted hospital stays have also been reported, according to a survey among radiologists. (106) The same benefits have been found when MRI was used; diagnostic work-up and management plans were affected favourably (30).

In paper 3, by assessing the economic effects of introduction of new technology, we only compared the total costs of patient care during the diagnostic work-up. In doing so, we insured that our estimate is maximally conservative. If the whole patient episode had been covered, the effects of the higher diagnostic accuracy of the new

methods and the reduction in diagnostic work-up time on the clinical outcome would probably have added further to the observed pay-off. Commendable consequences were a more favourable course of the disease with further reduced length of stay and less treatment for morbidity complications. If the calculations had included costs outside the hospital, e.g. social services and home care costs as well as loss of income and burden on relatives, the benefits would have appeared even greater.

Even with our conservative approach, our study justifies the conclusion that costly investments in medical technology give returns by in-patient care saving.

The transition from a system of conventional film-screen radiology to a digital filmless hospital requires careful planning. One alternative is to digitize one modality at a time, which results in a transitional phase during which both hard and soft-copy images are produced simultaneously; this was done in our study (paper II). Another alternative is to make the whole hospital filmless overnight with no transitional period (97).

Replacing conventional radiography with a PACS throughout the hospital has been considered cost-effective because it reduces both the operating costs of the radiological department and the time that patients stay in hospital. (9, 91) Digital radiology has thus been shown to pay for itself within 5-11 years (4, 75). In contrast, it has been argued that a PACS does not reduce the running costs of a radiological department (1, 84).

Our study shows that the acquisition of CR equipment cannot be justified by cost benefits unless it leads to a complete PACS with picture archiving and an image distribution network throughout the hospital, thus drastically reducing the use of film.

Step-by-step acquisition of CR with a planned transition to more extensive digitization can be justified by the better quality of examinations during the transition period. In the experiences of Hruby (48), a PACS that covers the entire hospital pays for itself within 5 years. The cost benefit is seen to be the result not only of the reduced film and archive costs but also of the faster distribution of information, which tends to reduce the length of a patient's stay in hospital. If all the advantages provided by PACS were utilised in the Central Hospital of Vaasa (paper II), the reduction in film costs would be about FIM 700, 000 per year, and in image sorting and traffic about FIM 600, 000 per year. In addition, the building of a new conventional film archive, which is already planned, would no longer be necessary.

6.2 Conventional and activity based costing

Effective information management is said to be probably the most critical success factor enabling an institution to (1) identify and quantify opportunities for improvement, (2) improve process flow, (3) measure and monitor the results of re-organisation, (4) disseminate information to all those who need to know and (5) improve overall decision-making capabilities. (35, 80)

Privatisation of government owned monopolies, deregulation, intensive competition and expanded product range created the need for service organizations to develop management accounting systems that enabled them to understand their cost base and determine the sources of profitability for their products/services, customers and markets. Many service organisations, like hospitals, have therefore recently implemented management accounting systems.

ABC (activity-based costing), a method designed for accurately costing a product or service based on a process description of the product, has been implemented successfully in various manufacturing and servicing organisations (19). There have so far been only a few reports on the implementation of ABC in health care (24). A Canadian model of laboratory costing provides more accurate product cost information than do conventional costing systems. (19) In our studies we have developed, tested and applied ABC in a radiological unit, and at the time this was the first report in the literature (paper I and II).

With ABC, it is possible to examine the life cycle of a process. It is seems to be possible to include itemised costs for product design, product development, and production and quality assurance. In our study quality assurance and product development costs were low, because during the study period no specific product development projects were undertaken; only routine quality assurance activity was performed.

As shown in our studies, ABC is an important management tool in the radiology department. Work processes are described as activities with known unit costs. Cost management can be directed at activities where the cost-benefit balance is unfavourable. After a unit cost assessment, measures can be taken to change the way in which an activity is performed or the way in which resources are distributed between activities. These managerial actions may be of strategic importance. (17,35) Poor structuring of activities can lead to missed deadlines, unfinished projects, disappointed customers and non-value-added costs. The redesign of activities may be organised by applying CQI (continuous quality improvement) techniques, since both are based on a process approach. (17).

ABC allows discrimination between patients of different kinds according to their needs. For example, we compared procedures done in the ward with procedures performed in the radiological department; the latter were less costly. These features, though important for activity planning, are typically not dealt with in the radiological literature.

6.3 Significance of quality management

The health care sector differs from the industry or service sector. Health care is highly professional, concentrating on what is very important for an individual, health. Radiology further differs from other areas of health care in being very capital intensive and developing rapidly in information technology. In the past there have been attempts to introduce managerial methods from the process industry into health care, but with little success. The management methods that are important and suitable in health care are somewhat different from those needed in other sectors. Because there is a great demand for effective use of resources, the focus of the management methods is on improving cost-effectiveness and maintaining or even increasing the quality of diagnostics and treatments in radiological procedures.

We primarily tested one measure of quality, effectiveness, in the diagnosis of meningioma and, at the same time, showed the effects of developing radiological methods. Subsequently we used it for measuring the treatment of chronic critical ischaemia.

The outcome for the patient is the single most important factor in medical decision-making, i.e. when choosing clinical treatment strategies. Increasingly, physicians are

required to make such decisions on the basis of evidence, so-called evidence-based medicine, the ideal being the clinical effectiveness of a therapy demonstrated in a randomised, controlled trial. The utilisation of resources and hence the costs of care are, to a larger extent than medical decision making, dependent on the health care system, the environment of care facilities as well as the organisation and the processes of the professional services provided. Assessments aimed at comparing costs and cost-effectiveness need to take these considerations into account. An ideal situation is to use the information available from RCTs (randomised controlled trial) to choose treatment strategies for which a similar outcome may be expected and to study their implementation in terms of cost-effectiveness with an observational approach.

Two RCTs comparing PTA with reconstructive surgery on patients with chronic critical ischaemia of the lower limb, showed no difference in clinical effectiveness. (46, 104) Our cost-effectiveness study was based on register data and thus observational. (8) As the costs of PTA were only half the costs of surgery, and there was no difference in clinical outcome, PTA showed a more beneficial cost-effectiveness ratio than surgery. In cases where neither method can be expected to be superior, the radiological treatment approach should be chosen out of cost reasons.

SPC (statistical process control) methods are especially designed to measure quality in industry. These methods can also be used in health care. We tested and used SPC methods in the CQI paper (paper V), demonstrating the results by flow-charts, cause-and-effect diagrams, a Pareto chart and a control chart, a so-called p-chart. These are found to be useful in visualising and measuring the quality of service in health care. CQI is more powerful if implemented appropriately. It is necessary to monitor the

improvement (outcome) continuously, if the process is critical to the mission of the department's service.

RM (resource management) involves basic principles of health care: 1. Shared understanding and agreement by all participants, including clinicians and nurses. 2. The need for information systems. (81, 86) In this context EBM (evidence-based medicine) can be seen to have a different meaning, i.e. to be management based on evidence, which can be applied to radiology.

Later, at least in the USA setting, tools have been introduced for resource management. (80) The basic elements are to obtain the commitment of all the important groups of personnel and to give and share important information concurrently with staff education. Information implies not only the normal budgetary information, but also quality information, efficacy, effectiveness, cost information, ABC and cost-effectiveness. Guidelines, protocols and benchmarking processes are useful to the organisation because they give threshold values. The work and the way patients pass through the health care sector has to be seen as a process, a critical pathway. Continuous quality improvement is an effective method for implementing changes and in complex problems, such as interprofessional communications, should be preferred. There should be continuous focusing on outcome management, giving cost-effective, high quality diagnoses and therapy with customer/patient satisfaction. Incentive alignments are more common in the private sector and in the USA, but are not yet used very much in the Finnish hospital system.

In previous studies the implementation of CQI was also successful in radiology. (12, 45, 85, 90) However, our study clearly showed that the CQI method really is more

powerful than the conventional methods. In our study, CQI resulted in a 34% improvement in the delay at HUCH, there being no improvement in the controls.

CQI is included in quality management methods, such as TQM (total quality management). They both concentrate on quality issues. TQM includes quality assurance, i.e. auditing and accreditation. Systematic process improvement is primarily introduced into quality management. CQI is analytical and scientific in nature and rests on the assumptions that in complex systems the problems are attributable to weaknesses in the process, not in the staff members, who are professional in their own work. The whole process is split up among an expert team whose members have together the expertise required for all the individual steps in the process. CQI permits a thorough knowledge of the complex process and selection of critical focal points. Often, the problems seem simple and easy to handle by ordinary management approaches without a more time consuming and expensive CQI process. However, with ordinary management the intervention is done without studying the process carefully and analytically, and the opportunity to understand the complex process will then be missed. The strengths of the CQI process are the better analysis of the problem while, at the same time, the personnel involved in the process is committed to the necessary changes.

An important element of CQI is the quality management circle, which is used repeatedly to achieve continuous improvement. In our study, this was not carried out at the CQI department, which obviously explains why some of the gains were lost during the follow-up. This was also the case with Seltzer et al. (90) An easy method is needed for monitoring the process after the intervention. To obtain control material from the RIS data is nowadays easy. In the near future, when all the data for the patient are in an electronic format, it will be possible to measure the length of the

whole process, from the point of ordering the examination to obtaining the final report. Measuring, as we did, the performance of a round-the-clock radiological department only by examining the data for chest radiography simplified the monitoring still further. The CQI process should be continuous and an important part of future studies will be to evaluate the CQI with a longer follow-up time.

Activity-based management (ABM) is a process that focuses on improving costs and outcomes. It derives useful information from the way people think (their activities) rather than from traditional expense categories. ABM supports outcomes, quality, teams, re-engineering, empowerment, and continuous improvement (3, 35). We did not use ABM in our studies.

Activity accounting provides the information crucial for activity-based management. It gives managerial information for ABM. It is possible to use the earlier described basic principles for continuous improvement. It may be expected to be effective in a radiological department. The present study has only piloted some aspects of ABC. Practical improvements and scientific evaluation of the use of ABC for ABM, is much needed.

The new managerial methods employed in this study have clearly proven to be more effective than the conventional methods. The RM approach includes the basic principle of management in health care and also in a radiological department. It focuses on basic “business” processes, the diagnosis or treatment of the patient, with commitment of the most important personnel groups, including the physicians. It also includes qualified management measuring methods. Efficacy and effectiveness are suitable for measuring the quality of the diagnostics and treatments. With increasing demands for the more effective use of the resources, there should also be

measurement of costs. ABC is a cost accounting method superior in accuracy for measuring both the professional and the managerial aspects of radiology. Cost-effectiveness methods are suitable for measuring the professional aspect of the radiological work. For measuring the aspect of service quality, SPC methods are useful. And finally, for making managerial changes, we have shown that the CQI approach has advantages in comparison with ordinary management. It can also be used when we are concerned with problems and measurements other than those of pure service quality. It can be used for managing changes in efficacy and effectiveness. It can easily be adapted for ABC cost accounting and is then called the ABM approach.

7. CONCLUSIONS

On the basis of this study the following conclusions can be drawn:

1. Radiology is capital intensive and developing fast, but with modern technology the costs of diagnosis are decreasing strikingly. At the same time the diagnostic methods have become more accurate and convenient for the patient and also allow an earlier diagnosis. Thus, focusing only on cutting the costs of investment in equipment, especially in radiology, actually increases the cost of the diagnostic work-up. The revolution in radiology that is now in progress is the digitalization. Our results show that the stepwise transition to PACS is expensive: a partially digitized department only increases the running costs. Digititalization should lead to complete PACS, with image archives and an image distribution network throughout the hospital.
2. Calculations of the cost-effectiveness of PTA and vascular surgery showed a slightly better clinical outcome for the vascular surgery group, but PTA was found to be a feasible and more cost-effective procedure in chronic critical ischaemia of the lower limb. Nowadays there is a battle for resources. The decision makers need numerical facts from the medical services. Medicine should be evidence-based and the cost included in decision making. The treatment of critical leg ischaemia is an example of an area in which radiological treatment is compared with surgical treatment. The decision maker for the treatment is actually the vascular surgeon, not the radiologist. That is why it is extremely important to show him the benefits of radiological treatment in terms of effectiveness and costs.
3. ABC costing is superior to the conventional method. In our study the overhead costs as a proportion of the total product costs dropped from the original level

to one fourth. At the same time, ABC gives a good picture of the usage of resources in different activities. It can be used in both the professional and the managerial aspect of radiological patient/work flow.

4. In this study, the new managerial methods have been shown to offer several benefits in comparison with conventional ones. TQM and CQI are valuable methods for managing general service quality, but this is not enough. In all branches of health care, including radiology, quality has to be measured in terms of efficacy and effectiveness. Because of the consciousness of rising costs, there is also a great need to measure resource usage. ABC and ABM provide the support needed for such quality issues. To make the managerial method effective, it is important to bear in mind the principles of RM. The focus should be on the main processes, i.e. the critical pathways of diagnostics and treatment. Physicians as well as nurses and all other personnel groups involved in the process managed should participate in order to become committed. They have to have an accurate information system to demonstrate the quality and resource usage issues. For management of changes, the CQI approach is shown to be superior to the conventional approach and it should also be adapted for efficacy, effectiveness and ABM.

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